Influence of Food Supplementation on the Urinary Urea/Creatinine (U/C) Ratio of the Child

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There is evidence that calorie and protein-calorie supplementation of pregnant women from rural populations of Guatemala decreased the prevalence of intrauterine growth retardation. Moreover, results during pregnancy indicate that the two types of food supplement tested: calorie (fresco) and protein-calorie (atole) produced a similar effect on fetal growth.[1]

One explanation for these results is that calories were the main limiting factor in the home diet. The present paper aims to further explore the hypothesis that the main limiting nutrient is energy by analyzing the effects of these two types of supplements, fresco and atole, on the children's urinary urea/creatinine (U/C) ratio of the same rural populations previously studied.

Methods

A. Experimental design

The present data came from an ongoing longitudinal study in Guatemala which focused on the effects of mild-to-moderate malnutrition on physical growth and mental development.[2] Table I outlines the main characteristics of the experimental design. Two types of supplement are provided: atole* and fresco**. Attendance to the supplementation centre was voluntary and there was a wide range of supplement intake during pregnancy and lactation. The following variables were measured: supplement ingestion, home dietary intake, physical growth, mental development, morbidity and family sociocultural characteristics.

Table II presents the nutrient content for both atole and fresco. It should be noted that the fresco contains no protein and that it provides only one third of the calories contained by an equal volume of atole. In addition, both preparations contain similar concentrations of the vitamins and minerals which presumably are deficient in the diets of this population.

Table I

Experimental design

Four villages	Two villages: Atole*	= protein-calorie supplement
	Two villages: Fresco**	= calorie supplement

Maternal and child information collected from conception to 84 months of postnatal age

1. Obstetrical history†
2. Measurement of attendance to feeding centre and amount of supplement ingested per individual
3. Clinical examination
4. Anthropometry
5. Dietary survey
6. Morbidity survey
7. Socioeconomic survey of the family
8. Information on delivery
9. Assessment of mental development

* The name of a gruel commonly made with corn.
** Spanish for refreshing, cool drink.
† Diagnosis of pregnancy by absence of menstruation.

B. Description of the population

The study villages have a median total family income of about $200 per year. The typical house is built of adobe, few homes have sanitary facilities and drinking water is grossly contaminated.

Corn and beans are the principal components of the home diet, animal protein comprising a small proportion (12%) of the total protein ingested. One-day recall dietary surveys indicated that the intake is about 1,500 calories and 40 grams of protein daily throughout pregnancy. For children 2 to 5 years old

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* The name of a gruel commonly made with corn.
** Spanish for refreshing, cool drink.

Table II

Nutrient content per cup* (180 ml)

	Type of supplement	
	Atole	Fresco
Total calories (kcal)	163	59
Protein (g)	11	—
Fats (g)	0.7	—
Carbohydrates (g)	27	15.3
Ascorbic acid (mg)	4.0	4.0
Calcium (g)	0.4	—
Phosphorus (g)	0.3	—
Thiamine (mg)	1.1	1.1
Riboflavin (mg)	1.5	1.5
Niacin (mg)	18.5	18.5
Vitamin A (mg)	1.2	1.2
Iron (mg)	5.4	5.0
Fluor (mg)	0.2	0.2

* Figures rounded to the nearest tenth.

the intake is 71 calories and 2.0 grams of protein per kilogram of body weight per day, respectively.

Children are severely retarded in physical growth, most of them falling below the 10th percentile of the Denver standards[3] for weight and height by 7 years of age.

In summary, these data indicate that chronic moderate malnutrition is highly prevalent and that apparently calorie intake is severely limited in the diet of this population.

C. The variables

The amount of supplement ingested at quarterly intervals by lactating mothers, breast-fed and weaned children were the main independent variables. The main dependent variable was the urinary U/C ratio of the children as determined in a casual morning urine sample[4,5]. In addition, data on home protein intake, as estimated by 1- and 3-day recall surveys, were collected for children 15 to 60 months of age.

Casual morning urine samples were collected between June 1, 1973 and November 30, 1974 in children of the four villages at 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 42, 48, 60, 72 and 84 months of age. After immediate refrigeration at 4–6°C, the samples were transported to Guatemala City where urea, nitrogen, and creatinine, were determined in an autoanalyser;[6,7] the U/C ratio was then computed.

Table III presents the number of surveys performed by age group and type of supplement. Inspection of the coverage rates reveals that only a quarter of the surveys programmed in breast-fed infants were actually carried out because of the difficulty in obtaining an adequate sample volume of urine in this age group. In contrast, over 90% of the surveys programmed in older children were actually carried out. No significant differences were observed in coverage rates between fresco and atole villages.

Table III

Sample size. Number of urinary U/C ratio surveys

Group	Age (months)	Fresco	Atole	Total	Coverage (%)
Breast-fed infants	3–15	103	77	180	25.3
Weaned children	15–84	834	882	1716	90.2

Results

Means and standard deviations for home dietary intake, supplement ingestion and urinary U/C ratio are presented and discussed. Secondly, the relationship between supplement intake and U/C ratio is analysed.

A. Home dietary intake

Table IV presents the home protein intake for weaned children 15 to 60 months of age. It is clear that both home protein and calorie intake were slightly higher in the fresco group than in the atole group. Data is presented in Table IV which indicate that the risk of being protein underfed, computed from the dietary survey data, was between 6 and 13%. In contrast, the computed calories available for growth and physical activity were 26 to 32% of those observed in well-nourished populations of the same age.[8] These findings are similar to those observed in larger samples of the same population and point out that calories are the main limiting nutrient in the diet of this population. It is also clear in Table IV that protein intake in fresco villages was significantly higher than in atole villages.

B. Food supplementation

Table V gives the mean, standard deviation, and range of quarterly supplemented calories and protein for lactating mothers, infants, and weaned children up to 84 months of age. The atole groups ingested consistently larger amounts of calories than the fresco groups. This was principally due to the higher concentration of calories in the atole preparation.

C. Urinary U/C ratio

The data in Table VI indicate that the urinary U/C ratio for breast-fed and weaned children was consistently and significantly higher in the atole than in the fresco groups. This finding may be ascribed to the protein content of the atole. Though the home protein intake of the atole group was not higher than that in the fresco group, when the total nutrient intake of proteins is calculated (home diet plus supplement), the atole group had a substantially higher intake of proteins. Thus, in children 15 to 60 months of age the mean total protein intake was 2.8g per kg per day in the atole group, a figure significantly

Table IV

Home protein and calorie intake in children 15 to 60 months of age

Type of supplement	Number of surveys	Protein intake g/day*	g/kg/day*	Risk of protein under-feeding (%)**	Calorie intake cal/day*	cal/kg/day*	Mean percentage of required calories for growth and activity†
Fresco	660	23.6±9.4	2.11±0.89	6	954±356	85.2±31.8	32
Atole	724	21.4±8.5	1.91±0.75	13	812±291	72.5±26.0	26

* Mean ± standard deviation.

** Probability obtained from Z value, computed: $Z\frac{I-R}{S}$; where I is the average protein intake, R is the estimated average requirement of this population and S is the estimated true standard deviation of the population intake after correcting for methodological error. Estimated values for R and S were: 1.35 and 0.50 protein/kg/day, respectively[8] (Division of Human Development, INCAP, unpublished data, 1975).

† Computed dividing the difference: average calorie intake minus requirements for basal metabolism in the study population over the same difference in well-nourished populations of same age[8].

Table V

Amount of supplemented calories and protein per quarters

Group	Type of supplement	Calories Mean	Calories SD	Calories Range	Protein (g) Mean	Protein (g) SD	Protein (g) Range	n
Lactating	Fresco	5,323	5,295	0–23,800	0	0	0	103
mothers	Atole	19,893	19,585	0–82,000	1342.8	1322.0	0–5535.0	77
Breast-fed infants	Fresco	392	411	0–2,000	0	0	0	103
3–12 months	Atole	6,632	7,573	0–30,200	447.7	511.2	0–2038.5	77
Weaned children	Fresco	3,716	3,233	0–15,600	0	0	0	834
15–84 months	Atole	13,254	10,800	0–59,000	894.6	729.0	0–3982.5	882

higher ($p < 0.001$) than that of 2.1g per kg per day in the fresco group.

Assuming that most of the protein ingested in suckling children came from breast milk, the average U/C ratio in breast-fed suckling infants indicates that the mean protein intake was 1.05 and 1.25g of protein per kg per day in the fresco and the atole populations, respectively.*

These figures are similar to those obtained in a small sub-sample of 29 six-month-old children from the same population who were being fed exclusively by breast milk. In this sub-study (Division of Human Development, INCAP. Unpublished data, 1975), twenty-four-hour determinations of breast milk volume by the weighing method and analyses of the milk resulted in daily intakes per kg of 1.35± 0.34g of protein and 75±24 calories (mean ±1 SD, respectively.)

The estimated "safe" level of protein intake for this age is 1.4g of milk protein per kg per day. In contrast, the intake of calories in breast-fed infants was low, providing only 20% of the calories available for growth and physical activity in well-nourished populations (computed from ref. 8).

Because of the scarcity of reference data for children 3 to 7 years old fed with calorie deficient diets

*Computed from the equation: g. protein/kg/day = $\frac{\text{units U/C} - 0.8}{6.3}$. This equation was derived from G. Arroyave (Personal communication 1975).

Table VI

Urinary U/C ratio in pre-school children

Group	Type of supplement	Mean	SD	Range	Number of surveys
Breast-fed infants	Fresco	7.44	4.86	1.40–31.33	103
3–12 months	Atole	8.68	5.59	1.80–24.38	77
Weaned children	Fresco	9.56	3.73	1.50–44.00	810
15–84 months	Atole	11.45	4.56	0.13–36.25	855

made up of different proportions of corn, beans and animal protein, it is difficult to make inferences from the data on U/C ratio of the weaned children in the fresco group.

D. Relationship between food supplementation and urinary U/C ratio

Table VII presents the observed association between supplement intake and the children's urinary U/C ratio. All the correlations are summary values obtained in the usual way by pooling within age covariance and variance terms.[9]

Table VII

Correlation between fresco and atole intake and the urinary U/C ratio of pre-school children*

Group	Type of supplement*		Average correlation (r)	p value (less than)	n
Lactating mother**	Fresco		0.148	0.100	103
	Atole		0.288	0.010	77
	Total		0.253	0.001	180
Breast-fed infants 3–12 months†	Fresco		−0.150	0.100	103
	Atole		0.645	0.001	77
Weaned children 15–84 months combined**	Fresco		−0.145	0.001	834
	Atole		0.155	0.001	882
Weaned children 15–60 months†, ‡	Fresco	Before	−0.093	0.05	660
		After	−0.135	0.001	660
	Atole	Before	0.250	0.001	724
		After	0.261	0.001	724

* Fresco and atole intake was expressed in terms of calories.

** Covariance analysis between fresco and atole = NS ($p > 0.05$).

† Covariance analysis between fresco and atole = $p < 0.001$.

‡ Before and after controlling for home protein intake computed in a multiple regression predicting U/C ratio.

1. *Lactating mothers*

A positive association was observed between maternal supplement intake and the U/C ratio of their infants; the association did not differ significantly by type of supplement. The results in the fresco group correspond to those expected if calories are the main limiting nutrient in this population. Considering this caloric limitation, the calories given to the lactating mother may have improved the utilization of ingested protein, leading, therefore, to an increment of the breast milk protein supply to the child and consequently to an increase of the infant's urinary U/C ratio. It should be stressed that 10,000 calories of atole per quarter are accompanied by 0.15g protein/kg/day to the lactating mother.* Ten thousand calories in the mother led to a change of 0.82 units of the U/C ratio in the atole sample, while in the fresco sample the comparable statistic was 1.36; covariance analyses did not reveal significant differences between these slopes. The fact that the additional protein the mother received did not produce a higher urinary U/C ratio in the baby, supports the hypothesis that increments above 0.40g of protein per kg per day (that is, 50% above home diet protein) are required to produce higher maternal protein supply to the fetus.[9] Thus, providing calories alone to the lactating women of these populations resulted in an apparently similar efficiency to increase breast milk protein supply to the child than providing calories plus 0.15g of protein per kg per day. The dose response relationship observed in lactating mothers from both the fresco and atole groups (0.866 U/C units/10,000 cal.) would mean that 10,000 supplemented calories per quarter lead, on the average, to an increment of around 0.16g of breast milk protein per kg per day to their infants.† In other words, the extra calories provided to the lactating mothers allowed them to spare, on the average, around 1g of protein per day, this being enough to produce an increment of 90g of infant's weight per 10,000 calories supplemented per trimester.‡

2. *Breast-fed and weaned children*

In contrast to what occurs in the case of mothers, the data in Table VII indicate that the relationship between supplement intake in children and the U/C ratio depends upon the type of supplement given. Thus, the higher the intake of fresco (calories), the lower the U/C ratio, while the higher the ingestion of proteins and calories (atole), the higher the U/C ratio. A comparison of the associations observed in the atole and fresco villages revealed that they were significantly different from each other for both breast-fed and weaned children (test of covariance: $p < 0.01$).

These contrasting relationships between atole and fresco intake and U/C ratios could be explained in

* 10,000 cal/quarter = 690 g protein/quarter = 7.7 g protein/day = 0.15 g protein/kg/day, assuming an average maternal weight of 50 kg.

† 10,000 supplemented calories to the mother, produced an increment of 0.9 units of U/C in the infant, which is equivalent to an increment of 0.16 g of protein/kg/day.

‡ An increase of 0.16 g of protein/kg/day is equivalent to an increment of about 1 g protein/day (assuming average weight of 6.5 kg for this age group). If 20% of this increment in protein intake is used for growth[8], it would be equivalent to an increment of 0.2 g of tissue protein or 1 g of body mass per day, that is, an increment of around 90 g of weight per 10,000 supplemented calories per quarter.

several ways. It could be, for instance, that the calories ingested from the fresco partly replaced protein ingestion from the home diet; in other words children with higher intakes of fresco ingested lesser amounts of proteins and vice versa. This would explain therefore, the negative relationship observed between fresco intake and U/C ratios. To test this possibility, the partial correlation between supplemented calories from the fresco and the U/C ratio after controlling for home protein ingestion was calculated for children 15 to 60 months of age. These analyses were carried out for the atole group as well. The results, shown at the bottom of Table VII, indicate that home protein ingestion could not explain the differing patterns of relationships observed because the correlations between atole and fresco intake and the U/C ratio remained in the same direction and of practically the same magnitude after controlling for home protein intake.

The data shown in Table V indicate that the mean caloric intake from the fresco as well as the range are substantially below those observed in the atole group. It may be that the negative findings observed between fresco intake and the U/C ratios were due to phenomena operant in the lower ranges of caloric intake. To address this question, the relationship between atole intake and U/C ratios was investigated in those cases ingesting an amount of calories below the maximum range observed in the fresco group. In this subgroup, the association between supplemented calories and urinary U/C ratio was also positive ($r = 0.110$; $n - 466$ $p < 0.05$). Although a reduction was observed in the correlation value, this was not statistically different from that observed in the entire 15–84 months atole group (see Table VII).

Thus, in contrast to the findings in lactating mothers, the relationship between supplement intake of the breast-fed infant and of the weaned child and the U/C ratio differed depending upon whether the supplement contained protein or not. Specifically, protein–calorie supplementation of the child produced a notable increment of the urinary U/C ratio while calorie supplementation alone led to a decrease of the U/C ratio. The findings in the atole group are consistent with those in the literature[10] and explained by an increment of the rate of protein turnover and urinary excretion of urea[11,13]. The results in the fresco group may be explained by caloric limitation. Under this condition, calorie supplementation alone may lead to improved protein utilization for synthesis, lower protein catabolic rates and therefore, to a decrement of urea excretion and of the urinary U/C ratio. In other words, in the fresco group, part of the ingested protein otherwise burned to provide energy may have been spared.[14]

3. *Implications of the findings in children*

The data reviewed suggest that under caloric limitations, caloric supplements will spare protein from being burned as energy. If this is true, then more protein will be available for growth and one would expect growth rates to be improved as a result. Unfortunately, there is no quantitative information available on the impact of decreased protein catabolic rates upon protein utilization for growth in children 15 to 84 months. This precludes, therefore, estimations regarding the amount of protein to be spared per supplemented calorie under conditions of caloric limitation.

Further, it is difficult to say whether supplemented proteins would have an additional impact beyond that produced by calories. In the particular study reviewed here the question becomes whether the protein contained in the atole would have an additional effect beyond that produced by the sparing effect of calories. In weaned children 15 to 84 months of age, the amount of protein supplemented averaged around 1.0g per kg per day. Whether this protein will have an impact on growth depends upon how much additional protein is needed to produce an increment in nitrogen balance additional to that produced by the sparing effect of calories. For example, if the additional protein needed is similar to that estimated for pregnant women (around 50% of home protein intake in this population), atole children should grow better than fresco children for the same amount of supplemented calories.

E. Controlling for measurement reliability

Finally, an estimation of the test–retest correlation or measurement reliability of the variables is necessary to understand the quantitative importance of the associations between supplemented calories and U/C ratios presented in Table VII. The estimated measurement variability of supplement intake is very high ($r = 0.99$) while that for the U/C ratio is quite low ($r = 0.28$). Based on these values the maximum expected correlation will be 0.53 if the association between both variables is perfect ("perfect" $r = 1$).* In other words, only 28% of the variance in U/C ratio could be explained by supplemented calories since the rest (72%) was due to measurement error and intrapersonal variation.

The correlations observed in Table VII for children 15 to 60 months of age indicate that from 2 to 9% of the variance in U/C ratio was "explained" by supplemented calories. This means that, if the two variables had neither measurement error nor intrapersonal variation, the observed correlations between both variables would range from 0.3 to 0.6. Therefore, the correlations presented in Table VII are biologically important when related to the small "explainable" variance in U/C ratio.

* Maximum expected $r = \sqrt{0.99 \times 0.28} = 0.53$.

Comments

An analysis of the average home dietary intake estimated by dietary surveys and of mean U/C ratio in fresco villages brought support to the hypothesis that calories were the main limiting factor in the diet of this population. These results are compatible with previous reports in a larger sample indicating an effect of supplemented calories on fetal growth, which was apparently independent of whether supplement provided proteins or not.[1]

In summary, it is concluded that in this population calories are the main limiting factor in the diet of lactating mothers, breast-fed infants and weaned children up to 7 years of age. Therefore, an increment of caloric intake alone will produce: (1) in the lactating mother, enough protein spared to increase significantly the breast milk protein supplied to the infant, and (2) in the infants and children an increment in the proportion of ingested protein available for growth.

It should be stressed, however, that although calories were the main limiting factor in the diet of this population, excessive amounts of caloric supplementation alone may lower the protein–calorie ratio below the "safe" levels of intake and therefore it may increase the risk of protein malnutrition[15]. In consequence, decisions to implement caloric supplementation alone in populations similar to those herein studied should deserve careful consideration of this risk.

Summary

This paper investigates the relationship between intake of two types of supplements, caloric (fresco) and protein–caloric (atole), on the urinary U/C ratio in children from four rural Guatemalan villages. Atole was distributed in two of the villages while in the other two fresco was provided. Daily amounts of individual ingestion of supplement were recorded for lactating mothers as well as for breast-fed and weaned children up to 84 months of age. The urinary U/C ratio of the children was determined in a casual morning urine sample.

Positive associations were observed between supplement ingestion in lactating mothers and the U/C ratio of breast-fed children in atole ($r = 0.288$, $n = 77$, $p < 0.01$) as well as in fresco ($r = 0.148$, $n = 103$, $p < 0.10$) villages. In contrast, the relationship between ingestion of the supplements in breast-fed and weaned children and the U/C ratio differed depending upon the type of supplement given. Thus, for the caloric supplement, fresco, the relationship was negative (breast-fed children: $r = 0.150$, $n = 103$, $p < 0.10$; weaned children: $r = 0.145$, $n = 834$, $p < 0.001$) while for the protein-calorie supplement, atole, the relationship was positive (breast-fed children: $r = 0.645$, $n = 77$, $p < 0.001$; weaned children: $r = 0.261$, $n = 724$, $p < 0.001$).

The positive relationship observed between protein–calorie supplementation in lactating mothers and the U/C ratio in their children suggest that protein ingestion of the lactating women increases protein output in breast milk. The findings with respect to caloric intake, deserve more extensive comment. It was concluded that these findings bring support to the hypothesis that calories are the main limiting factor in the diet of this population. Thus, giving calories to the lactating mother may have resulted in enough protein spared to increase the breast milk protein supplied to the suckling child and consequently to increase his U/C ratio. Similarly, the reduction observed in the U/C ratio of the child upon supplementing him with calories may indicate that the calories given spared protein ingested at the home from being used to provide energy.

In spite of the fact that the results, the first from free-living communities reported in the literature, suggest that caloric supplementation to lactating mothers and children led to a betterment of their nutritional status, it should be stressed that decision to implement calorie supplementation alone in other populations should deserve careful consideration of the main limiting dietary factors to avoid the possibility of increasing the risk of protein malnutrition.

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